SCH OA1
## Thermodynamics Test

1. For each of the following, label with a + for in increase in potential energy or a - for a decrease in potential energy. Be careful. One-half mark will be deducted for each incorrect response.

a) __+__ The formation of ethyne from its component elements.

b) __−__ Sand is used to make glass.

c) __−__ Calcium carbonate is formed by the addition of carbon dioxide to calcium oxide.

d) __+__ Growth of a Western Red Cedar (i.e. humongous tree).

e) __−__ Cellular respiration.

f) __−__ Formation of a cloud.

g) __−__ Sublimation of $H_2O(g)$ to $H_2O(s)$.

h) __−__ Reaction of propane with oxygen.

i) __+__ Reduction of tin (IV) oxide to tin (II) oxide.

j) __+__ Conversion of glucose to hexane.

2. Please write the combustion reaction of hexane $(C_6H_{14}(l))$ as thermodynamic equation and as a thermochemical equation. The heat of combustion of hexane is -4162.9 kJ

$$C_6H_{14}(l) + \frac{19}{2}O_2(g) \rightarrow 6CO_2(g) + 7H_2O(l) \quad \Delta H = -4162.9 \text{ kJ}$$

$$C_6H_{14}(l) + \frac{19}{2}O_2(g) \rightarrow 6CO_2(g) + 7H_2O(l) + 4162.9 \text{ kJ}$$
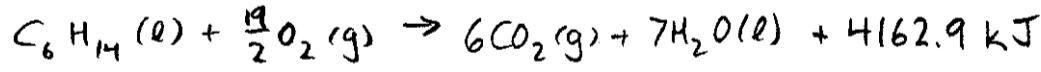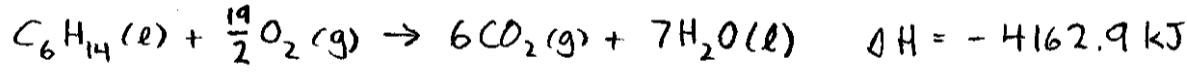
3. Calculate the heat of reaction for:

$2\,Al(NO_3)_3(aq) + 3\,(NH_4)_2SO_4(aq) \Rightarrow Al_2(SO_4)_3(s) + 6\,NH_4NO_3(s)$ ✓
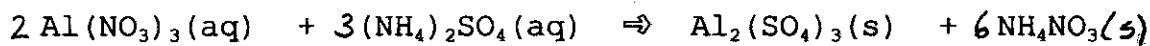
Using the following heats of formation and heats of formation listed in your text.

$\Delta H^{\circ}{}_{Al(NO3)3(aq)} = -273.65$ kcal

$\Delta H^{\circ}{}_{(NH4)2SO4(aq)} = -281.86$ kcal

$\Delta H^{\circ}{}_{Al2(SO4)3(s)} = -820.98$ kcal

$\Delta H^{\circ}{}_{NH_4NO_3(s)} = -365.6$ kJ·

$= -87.38$ kcal ✓

Please note that this is not a Hess' Law problem.

$\Delta H = \left[\Delta H^{\circ}{}_{Al_2(SO_4)_3(s)} + 6\,\Delta H^{\circ}{}_{NH_4NO_3(s)}\right] - \left[2\,\Delta H^{\circ}{}_{Al(NO_3)_3(aq)} + 3\,\Delta H^{\circ}{}_{(NH_4)_2SO_4(aq)}\right]$ ✓

$\Delta H = \left[-820.98\,kcal + 6(-87.38\,kcal)\right] - \left[2(-273.65\,kcal) + 3(-281.86\,kcal)\right]$

$\Delta H = 47.62\,kcal$ ✓

or

$199.24\,kJ$

(Circled ⑨ in left margin)

4. Determine the final temperature if 70.594 kJ of heat is added to 125 g of ice at 0°C. Useful information can be found in your text on page 307 and of course page 799.

Find heat absorbed by change of state $(H_2O(s)\ @\ 0°C \rightarrow H_2O(l)\ @\ 0°C)$

(Circled ⑨ in left margin)

$Q = L_F\,m$ ✓

$Q = \left(\dfrac{6.03\,kJ}{1\,mol} \times \dfrac{1\,mol}{18.02\,g}\right) \times 125\,g$ ✓

$Q = 41.829\,kJ$ ✓

Find heat not used to cause change of state

$70.594\,kJ - 41.829\,kJ = 28.765\,kJ$ ✓

Use remaining heat to warm water

$Q = 28.765\,kJ \rightarrow 28765\,J$

$m = 125\,g$

$c = 4.184\,J/g°C$

$\Delta T = ?$

$\Delta T = \dfrac{Q}{mc}$ ✓

$\Delta T = \dfrac{28765\,J}{125g \times 4.184\,J/g°C}$

$\Delta T = 55.00°C$ ✓

∴ the water warms by 55.00°C from 0°C to 55.00°C

5. Determine the mass of propane that must be combusted to warm 160 L of water from 15 °C to 52 °C. You may use any heats of formation from the textbook that you like.

(9)

$Q = ?$

$m = 160 L \rightarrow 160\,000 g$

$c = 4.184\, J/g°C$

$\Delta T = 52°C - 15°C = 37°C$

$Q = mc\Delta T$ ✓

$Q = 160\,000 g \times 4.184\, J/g°C \times 37°C$

$Q = 24769280\, J$ ✓

$Q = 24769\, kJ$ ✓

↗

this is the heat energy required

$C_3H_8\,(g) + 5\,O_2\,(g) \rightarrow 3CO_2\,(g) + 4H_2O\,(l) \qquad \Delta H = ?$ ✓
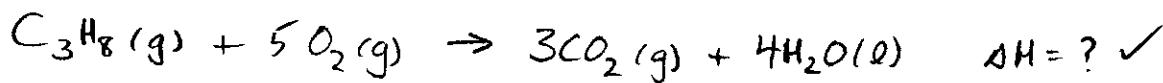
$\Delta H = [3\Delta H°_{CO_2\,(g)} + 4\,\Delta H°_{H_2O(l)}] - [\Delta H°_{C_3H_8\,(g)} + 5\,\Delta H°_{O_2\,(g)}]$ ✓

$\Delta H = [3(-393.5 kJ) + 4(-285.8\, kJ)] - [(-104.7\, kJ) + 5(0)]$

$\Delta H = -2219.0\, kJ$ ✓

$\Delta H = -Q$

$Q = 2219.0\, kJ/mol\ C_3H_8$ ✓

↗

heat released per mol of C_3H_8 combustion

$24769\, kJ \times \dfrac{1\,mol\ C_3H_8}{2219.0\, kJ} \times \dfrac{44.11 g\ C_3H_8}{1\,mol\ C_3H_8} = 492.37 g\ C_3H_8$ ✓ ✓ ✓ ✓

6. If 50 L of water is warmed by 11.469 °C by the combustion of 50 g of decane, determine the heat of formation of decane. This is not a Hess' Law problem. You may use any heats of formation that you wish from the textbook.

(9)

$Q = ?$

$m = 50L \Rightarrow 50\,000g$

$c = 4.184 \; J/_{g}°C$

$\Delta t = 11.469°C$

$Q = mc\Delta T$ ✓

$Q = 50\,000g \times 4.184 \, J/_{g}°C \times 11.469°C$

$Q = 2399314 J$ ✓

$Q = 2399.31 \, kJ$ ✓

$$\frac{2399.31 \, kJ}{50g \; C_{10}H_{22}} \times \frac{142.32g \; C_{10}H_{22}}{1 \, mol \; C_{10}H_{22}} = 6829.41 \, kJ/_{mol} \; C_{10}H_{22}$$ ✓ ✓ ✓

$\Delta H = -Q$ ✓

$\Delta H = -6829.41 \, kJ/_{mol} \; C_{10}H_{22}$

$\therefore \; C_{10}H_{22}(\ell) + \frac{31}{2}O_2(g) \rightarrow 10CO_2(g) + 11H_2O(\ell) \quad \Delta H = -6829.41 \, kJ$ ✓
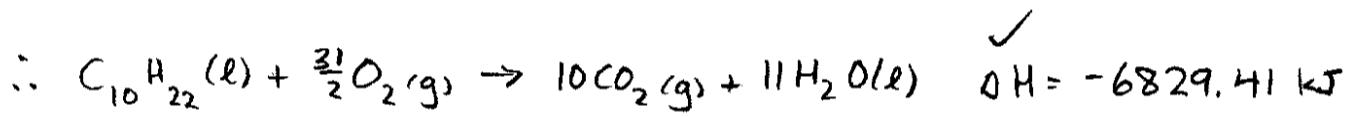
$\Delta H = \left[10\Delta H°_{CO_2(g)} + 11\Delta H°_{H_2O(\ell)} \right] - \left[\Delta H°_{C_{10}H_{22}(\ell)} + \frac{31}{2}\Delta H°_{O_2(g)} \right]$ ✓

✓✓

$-6829.41 \, kJ = \left[10(-393.5 \, kJ) + 11(-285.8 \, kJ) \right] - \left[\Delta H°_{C_{10}H_{22}(\ell)} + \frac{31}{2}(0) \right]$

$\therefore \; \Delta H°_{C_{10}H_{22}} = -249.39 \, kJ$ ✓

7. Use Hess' Law to find the heat of formation of ethane (C_2H_6) given:

① $C_2H_6(g) + \frac{1}{2}Cl_2(g) \Rightarrow C_2H_5Cl(g) + \frac{1}{2}H_2(g)$ $\Delta H° = 8.6$ kJ

② The heat of combustion of ethanol is -1409.2 kJ.

③ $C_2H_5Cl(g) + H_2O(\ell) \Rightarrow C_2H_5OH(\ell) + HCl(g)$ $\Delta H° = \cancel{11.1}$ 33.5 kJ
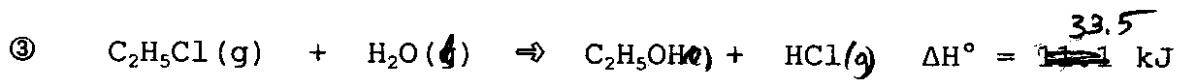
④ The heat of formation (and reaction thereof) for carbon dioxide gas.

⑤ The heat of formation (and reaction thereof) for water ~~vapour.~~

⑥ The heat of formation (and reaction thereof) for hydrogen chloride gas.

See text book for heats of formation and the answer!!

<u>find</u> $2C(s) + 3H_2(g) \rightarrow C_2H_6(g)$ ✓

Given

① $C_2H_6(g) + \frac{1}{2}Cl_2(g) \rightarrow C_2H_5Cl + \frac{1}{2}H_2(g)$ $\Delta H = 8.6$ kJ

② $C_2H_5OH(\ell) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(\ell)$ ✓ $\Delta H = -1409.2$ kJ

③ $C_2H_5Cl(g) + H_2O(g) \rightarrow C_2H_5OH(\ell) + HCl(g)$ $\Delta H = 33.5$ kJ

④ $C(s) + O_2(g) \rightarrow CO_2(g)$ ✓ $\Delta H = -393.5$ kJ

⑤ $H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(\ell)$ ✓ $\Delta H = -285.8$ kJ

⑥ $\frac{1}{2}H_2(g) + \frac{1}{2}Cl_2(g) \rightarrow HCl(g)$ ✓ $\Delta H = -92.3$ kJ

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rev ✓ ① $C_2H_5\cancel{Cl}(g) + \frac{1}{2}H_2(g) \rightarrow C_2H_6(g) + \cancel{\frac{1}{2}Cl_2}(g)$ $\Delta H = -8.6$ kJ

rev ✓ ③ $\cancel{C_2H_5OH(\ell)} + \cancel{HCl}(g) \rightarrow C_2H_5\cancel{Cl}(g) + \cancel{H_2O}(\ell)$ $\Delta H = -33.5$ kJ

rev ✓ ② $2\cancel{CO_2}(g) + 3\cancel{H_2O}(\ell) \rightarrow \cancel{C_2H_5OH(\ell)} + 3\cancel{O_2}(g)$ $\Delta H = 1409.2$ kJ

⑥ $\frac{1}{2}H_2(g) + \frac{1}{2}\cancel{Cl_2}(g) \rightarrow \cancel{HCl}(g)$ $\Delta H = -92.3$ kJ

✓ $2 \times$ ④ $2C(s) + \cancel{2O_2}(g) \rightarrow 2\cancel{CO_2}(g)$ $\Delta H = -787.0$ kJ

✓ $2 \times$ ⑤ $2H_2(g) + \cancel{O_2}(g) \rightarrow 2\cancel{H_2O}(\ell)$ $\Delta H = -571.6$ kJ

$2C(s) + 3H_2(g) \rightarrow C_2H_6(g)$ ✓ -83.8 kJ ✓